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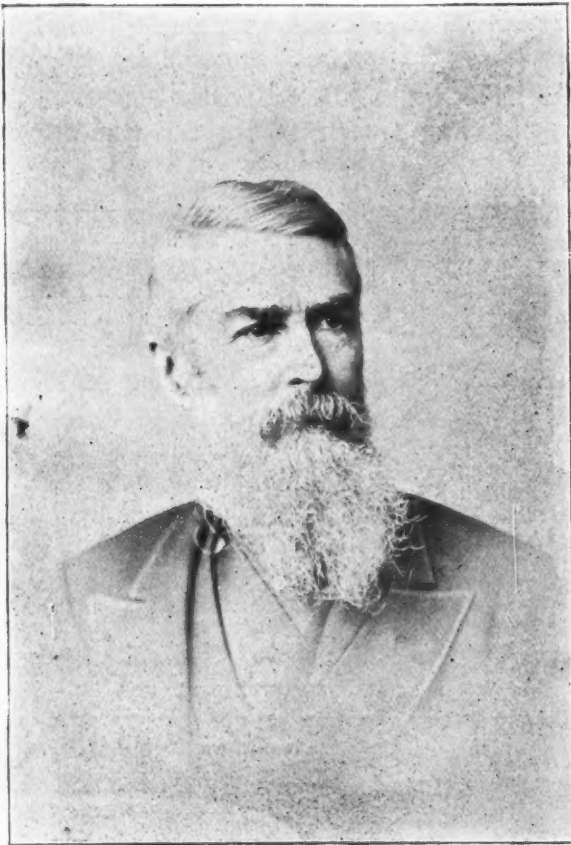
# Compressed Air

DEVOTED TO THE USEFUL APPLICATION  
OF COMPRESSED AIR.

VOL. I.

NEW YORK, MAY, 1896.

NO. 3



GENERAL HERMAN HAUPT.

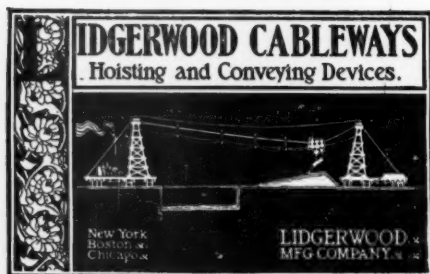
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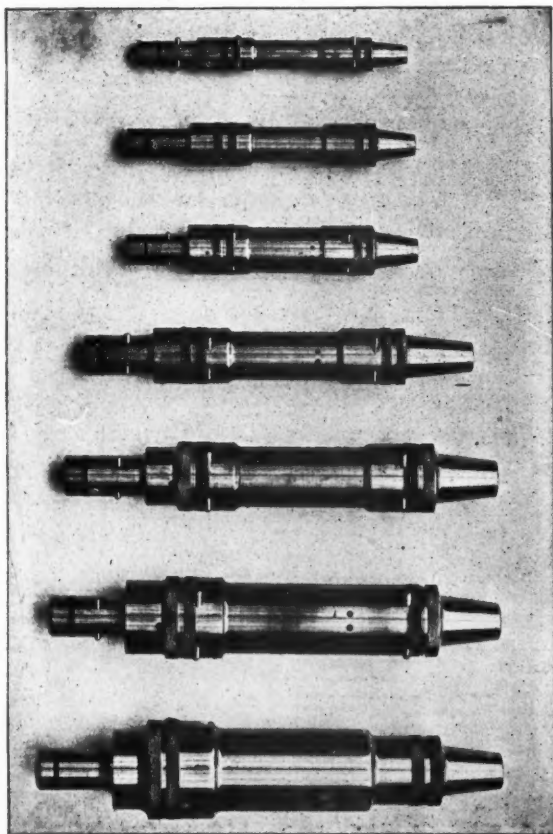
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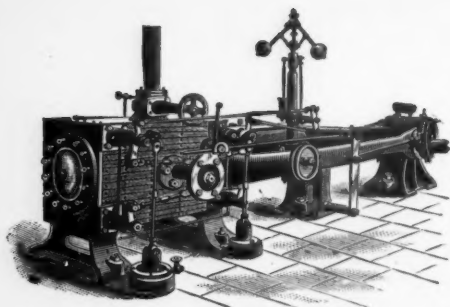
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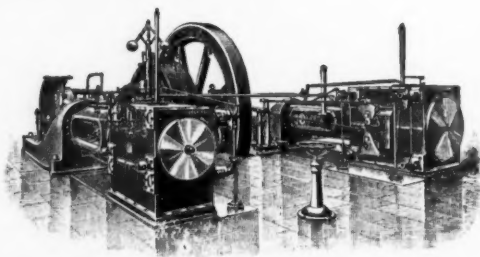
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## COMPRESSED AIR.



A MONTHLY PUBLICATION DEVOTED TO THE USEFUL  
APPLICATION OF COMPRESSED AIR.

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THE late Franklin Leonard Pope, a distinguished electrician, said that if but a fractional part of the money and brains that have been spent upon the development of electricity as a motive power for street railroads had been spent upon compressed air, we would now be riding on pneumatic tramways. This is a statement worthy of serious consideration. Prof. Hutton of Columbia College recently repeated it, quoting Mr. Pope's words, and expressing his own belief that compressed air offers much encouragement to experimenters in this line. The extensive development of the trolley is the result of brains, energy and money, which in all things is sure to win in the end. Nobody now doubts that electricity is well adapted for tramway work, nor does any unbiased person question the fact that the trolley, under certain conditions, is the best means of street car propulsion. But there are some places, and certain conditions, where the trolley either should not be used because of objectionable features, or, when

used, it does not accomplish the result in the most economical manner. This is the field for the compressed air motor.

It is well known among engineers that it is not economical to distribute power electrically unless that power is consumed as fast as it is produced. In other words, a dynamo developing, say, 50 H. P. and distributing it for power purposes, is not economical unless the motors consume the maximum available power at all times. If we have a short line of street cars, say one mile in length, as for instance a means of transporting passengers between a railway station and some other point, and desire to equip this line with a motive power other than horses, it is not likely that it would pay to equip with the trolley, because with one or two cars on the line running at infrequent intervals, there would be times when no part of the power generated at the central station would be required at the car, because there would be no car in motion; hence it would become necessary to either stop the engine which runs the dynamo, or to provide some other means of utilizing the electric current. Such a road as this calls for a storage system, and the best power for a storage system is compressed air.

THERE can scarcely be any doubt about the fact that there is a field for the storage system of street car propulsion, because so much time and money has been spent in efforts to perfect the storage battery. It is equally as clear that the electric storage battery system is a failure up to date. Whatever other reasons there may be for this, the principal difficulty is in the battery itself. This being the case, is it not surprising that some of this time and money is not spent upon some power other than electricity as a storage power? Compressed air is particularly well suited for this purpose. Nor is it a matter which involves much doubt as to the practicability

of compressed air as a power for propelling cars by the storage system. It is almost entirely a question of availability for specific purposes, of adaptability for tramway service; and in order to reach this point, experiments involving time, invention and money are of course necessary. The pneumatic locomotive, which has been built, and which is now used largely in mines and elsewhere, is an evidence of the practicability of compressed air as a tractive power. Some of the locomotives are of large size, others are small, and many of them have about the same power capacity as that required for street car propulsion. These locomotives store air at pressures varying from 400 to 2,000 pounds pressure per square inch. Many of them do not re-heat the air at all before use, and yet we venture to say that it would be a serious matter if those now using them should be called upon to stop, as we doubt that any power would be as useful, or in most cases as economical.

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To STORE compressed air and use it as a power is a very simple matter. There are many erroneous ideas on the subject, and much ignorance. In order to store compressed air, we must first have a receiver or tank sufficiently strong to withstand the pressure; then it is simply a question of an air compressor and plenty of free air. The popular idea is that there is an enormous amount of heat developed which in some mysterious way has a bad effect during compression and storage; that this heat all disappears, and that it is impossible to use this air without freezing, resulting in stoppage of ports and passages and serious hindrance to the machinery. The heat of compression is no longer a bugbear in air compression. It is now under control to such an extent that by compound compression, or by compressing in stages with inter-coolers between each stage, the heat produced by the compression of air is not

only reduced in degree, but the objections to it on the ground of economy no longer obtain. By the modern compound, condensing Corliss Air Compressor provided with quadruple compression cylinders and inter-coolers, compressed air may be delivered into the receiver at 2,000 pounds pressure, and at a temperature nearly equal to that at which it was taken into the compressor; that is, the temperature of the engine room or of the atmosphere surrounding it. The heat loss—that is, the loss of power due to the heat of compression, which a few years ago ran as high as 50 per cent.,—may now be brought down to 17 per cent. This large saving is due mainly to compound compression and inter-cooling, and it represents a marked advance in compressed air science. This fact alone should at least give compressed air engineers a hearing when pressing their claims for a better storage system of street car propulsion than has been or can be produced by electricity. After compression the air is stored in tubes, which are made of solid ingots of mild steel, free from joints and welds, capable of standing pressures from 2,000 to 4,000 pounds per square inch, and which do not explode. Even if an explosion should occur, or a weakness develop in the reservoir, there is not likely to be any serious result, because the rent which would quickly be made in the pipe would soon discharge its stored air. Were the material brittle the pieces might fly in all directions and do considerable damage, but the metal used for this purpose is soft and pliable, and would tear or stretch instead of break. A discharge or explosion from compressed air will not scald like steam, though it is likely to produce quite as much noise.

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Having compressed air stored in suitable receivers, it is simply a question of keeping them tight, and of providing a sufficient volume to run a car, locomotive or

any other traction engine. Almost any design of engine which runs by steam will run equally as well by compressed air, but an air motor designed for use with air is better and more economical. Pneumatic engineers have already developed reheaters by means of which the stored compressed air before use in the engine is very much increased in temperature; hence its volume is increased and less air is required to do a certain work than when used cold. Reheaters will, of course, overcome all liability to freezing, but the main purpose of a reheater is to save power. That it does this at an expense in fuel which is but insignificant in proportion to the gain, is a matter which cannot be disputed in view of recent facts of experience. Mr. Robert Hardie has practically demonstrated the fact that the cost of reheating air is about one-eighth the cost of compression. That is, it will only cost one-eighth as much to add a horse power to a compressed air volume as it originally costs to produce one horse power by the process of compression.

WITH the present issue we present to the general reading, not less than to the scientifically inclined, public, the third number of a publication which is, as all know, the first that has been devoted exclusively to that useful power, compressed air.

We publish herein extracts from a few of the large number of commendatory letters which greeted our initial copy, from which may be gathered the general realization of the need of a publication of this nature, and the previous widespread regret that none such appeared.

In these brief notes we have no intention of extolling the merits of "COMPRESSED AIR," but only to draw attention to the long-felt and imperative necessity, that the subject may be treated in a regular and not desultory manner, and to point out

that in these pages will be found matter that relates to the subject in hand, together with such dissertations on each progressive movement as shall be of benefit to all who are interested in this branch of science.

As articles in serial form will run through our paper, we wish to call attention to the advisability of subscribing *at once*, and thereby securing a copy of our earliest issue, and so preserving intact the files of what must prove to be a valuable addition to the scientific literature of the day, as the sole means, so far as printed matter may go, of keeping abreast with the uninterrupted advance of compressed air.

The more intimate knowledge that engineers, investors and other promoters of great undertakings have of means for prosecuting important works, the greater and more frequent will be the operations. Such work as harnessing Niagara, the Chicago Drainage Canal and the many other similar engineering works would not have been attempted unless the means of carrying them out speedily had not been apparent. Still other and greater works engross the minds of the world's progressive men.

The Nicaragua Canal which will unite the Atlantic and Pacific Oceans and open up a waterway of the utmost importance to the United States is at this time receiving attention by the U. S. Congress. It is in such a work as this that compressed air distinguishes itself.

The Chicago Drainage Canal owes its rapid completion, to a great extent, to this effective agent. The facility with which excavation can be done by its aid makes such work much less formidable than it once was. Colossal works lose the appearance of greatness before the improved appliances of the age, and compressed air is one of the most advanced of all factors.

## EARLY PNEUMATICS.

## III.

That genius of human progress who presides over the rapid supplying of man's needs, passing over electricity, water and steam, selects air as the force best adapted to serve his ends.

This benign spirit appeared in the person of a certain Dr. Denys Papin, who lived nearly two centuries ago in the quiet town of Blois, and under the rule of "le grand monarque," in beautiful France.

To this distinguished Frenchman we are indebted for the first suggestion of conveying compressed air through pipes as a means of transmitting power; and toward the end of the century, his fertile brain conceived the idea of projecting parcels through a tube by means of compressed air. Never before, in the history of inventions, did the application of this principle to such an end take form in the minds of the world's great scientists. Dr. Papin, therefore, stands to-day as the pioneer in that field.

After the death of the doctor, we are told, the invention took a sleep of a hundred years—which might be a long sleep for anything else, but is, for an invention, only a reasonable nap.

We do not hear again, therefore, of any atmospheric system of propulsion until 1810, when George Medhurst, a mechanical engineer, took out a patent in England "for a means of conveying goods, letters, parcels and passengers by means of a tube and a blast of compressed air."

In the same year he published a pamphlet on "A New Method of Conveying Letters and Goods with Great Certainty and Rapidity," in which appear the first *practical* suggestions for the introduction of what is now known as the "Pneumatic System." This work foreshadows almost everything since discovered in connection with the subject of air propulsion.

A little later in the year appeared another pamphlet by Medhurst, entitled, "A System of Inland Conveyance for Goods and Passengers." In the latter, unfortunately, the zeal of the inventor carried him beyond his limitations, and as a result, he made a failure of the car system—as, indeed, did Vallence, his English rival, and Pinkus, a clever American.

However, the system for conveying light goods, such as letters, parcels, etc., proved a complete success, and now in its perfected form it operates by connecting the tubes containing the carriers, one with a vacuum chamber and the other with a compressed air chamber, air being condensed behind the carrier in one and exhausted before it in the other at the same time by a double-barreled air pump, operated by an engine of one horse-power and attaining a speed of about forty miles an hour.

The first line of this system was controlled by "The Pneumatic Dispatch Tube Company" of London, in 1859, between Euston Square Station and the Post Office in Eversholt street, later extending its charter to Holborn. The entire distance covered is 3,080 yards, laid with easy gradients.

The telegraph offices of London were the next to eagerly adopt the new system for communicating with the central office. At each way station of the line is a receiving apparatus consisting of two short barrels, parallel with the main tube, either of which may be put in or out of connection with the line by means of a lever; one of these is open at both ends so as to allow a carrier to pass through unimpeded, but the other is almost entirely closed at one of its ends, so that when it is switched into line with the main tube it intercepts the carrier. Of course, the time when a carrier is expected to arrive is telegraphed to the receiving station.

To-day every great city in the world has its commerce facilitated by this ingenious device; and it would require only a little

time and thought on the part of the inventors of this age to perfect the passenger tube to such an extent as to make a luxurious pneumatic railway solve the burning question of transportation.

FRANCES MALOV.

### General Herman Haupt.

The subject of this sketch is President of the General Compressed Air Company, whose portrait we reproduce on our cover, is a high authority in all matters relating to compressed air, and was one of the earliest advocates and firmest believers in this useful power.

General Haupt was born in Philadelphia, March 26, 1817. In June, 1831, he was appointed a cadet to the United States Military Academy at West Point, graduating from there in June, 1835, in the class with General Meade. Shortly after graduation he resigned from the army to accept the position of assistant engineer on surveys near Philadelphia, which post he filled with great credit and ability.

In 1840, while connected with the York & Wrightsville Railroad, General Haupt began his investigations as to the principal causes of strains on bridges and trains, the result of which, in 1850, he gave to the world in his book on the "General Theory of Bridge Construction," which has won much fame for its author.

From 1842 to 1847 he occupied the chair of Professor of Mathematics and Civil Engineering in Pennsylvania College, and from that date until 1855 he was associated with the Pennsylvania Railroad, occupying almost every position of importance in the gift of the company, including that of General Superintendent, Chief Engineer, etc., and was finally elected a director of the company by the City Council of Philadelphia.

In 1862 General Haupt received a telegram from the Secretary of War, calling him to Washington, where he was appointed

Chief of Construction and Operation of the Military Railroads of the United States and Aid-de-Camp to General McDowell; and on September 5, 1863, was made Brigadier General for Maritime Service in the operations against the enemy during Pope's campaign.

From the close of the war until 1879, General Haupt was connected with various railroads, and in spite of the great amount of work he accomplished he still found time to compile many valuable reports and to contribute articles to numerous magazines which have been of great service to the profession.

In 1879 compressed air traction first attracted his attention, and after a thorough investigation of the system he reported on it favorably, but failed to secure its adoption owing to the universal prejudice then existing against it. Realizing that the time for the projection of his scheme was not yet ripe, General Haupt devoted his energies to the extension of several railway projects until 1892, when he resumed his efforts in favor of compressed air traction and brought out a work, "Haupt on Motors," in which the compressed air motor was strongly advocated.

General Haupt has been so closely identified with the principal railroad enterprises of this country during the past fifty years that it is impossible in this short notice to enumerate the many positions of trust and responsibility which he has filled. His "efforts and labors have ever been in the vanguard of progress; he has worked for his country and for the age in which he lived."

In conclusion, we cannot do better than quote from a letter recently written by one of General Haupt's many admirers, in which the achievements of his busy life are summed up in the following words: "In considering your life, I think of you first with your engineer corps pushing the surveys and building on the lines of the now great Pennsylvania Railroad thor-

ough fare through the Allegheny Mountains west; then I think of you during the trying days of the war serving the Government so faithfully in fighting for the great cause of freedom, and particularly your marvellous achievements in reconstructing the burned railways and other bridges in advance of Sherman's army, and which made his great 'march to the sea' possible. After the war, again you were found tunneling and completing the great Hoosac tunnel, now also an important thoroughfare; and later you labored in the construction of the Northern Pacific Railroad, which in itself was a sufficient undertaking for one man's life-time. Since then, all who have been associated in compressed air matters know the fight that you have made for the recognition of its great possibilities, and I trust that your present efforts may be crowned with the same success which has followed your judgment all through life."

J. E. QUINTERO.

EASTERN railroad men would do well to follow in the footsteps of their more progressive Western brethren, who for some time past have used compressed air for cleaning passenger cars. The device employed is a simple and economical one, and could be used to great advantage on all our roads.

THE New Orleans & Western Railroad Company is one of the first companies to use compressed air locomotives for the handling of cotton and other freight in terminal yards. The test of this system recently made by this company has proved so successful that we have no doubt that compressed air locomotives will soon be used in all the great terminal yards.

COMPRESSED air certainly has a field of usefulness and can accomplish much, with a decided saving in foundry practice. Anyone who will study the question carefully cannot but be convinced of the fact.

### The Freaks of Compressed Air.

During the forest fires at Hinckley, Minn., in the summer of 1894, the flames came to the brink of a lake half a mile wide. The water did not stop its progress as it ignited on the other side. One man fleeing for his life before the tornado of flame had almost given up the race, when some unknown force picked him up bodily and carried him along, without effort on his part and finally landed him out of danger. He told this story to wondering hearers who believed his statements but who could not fathom them.



Compressed Air Fender and Defender.

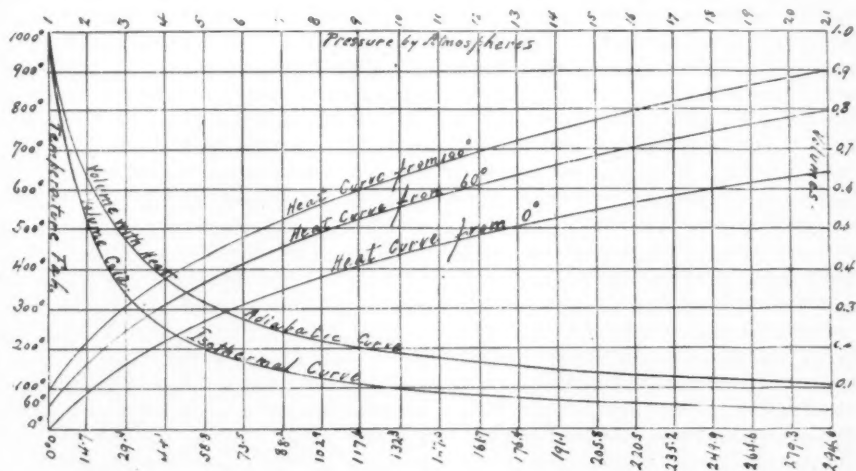
## COMPRESSED AIR.

(CONTINUED.)

The thermal results of air compression and expansion are shown by the accompanying diagram (Fig. 2—Frank Richards). Both the temperature of the air and its volume are shown at different stages of compression. The simplest application of this diagram is that which gives the gauge pressure represented at different points of the stroke. This is shown in the vertical lines. But in compressing air we produce heat, and it is important to know the tem-

peratures of the air at different stages of compression. The two curves which begin at the upper left hand corner and extend to the lower right are the lines of compression.

The upper one being the "Adiabatic" curve, or that which represents the pressure at any point on the stroke with the heat developed by compression remaining in the air; the lower is the "Isothermal," or the pressure curve uninfluenced by heat. The three curves which begin at the lower left hand corner and rise to the right, are heat curves and represent the increase of tem-



perature at any given pressure, also the relative volume. All of these are shown in the diagram. The initial volume of air equal to 1 is taken and divided into ten equal parts. Each division between two horizontal lines, shown by the figures at the right, representing one-tenth of the original volume.

The vertical and horizontal lines are the measures of volumes, pressures and temperatures. The figures at the top indicate pressures in atmospheres above a vacuum; the corresponding figures at the bottom denote pressures by the gauge. At the right are volumes from one-tenth to one. At the

peratures corresponding with different pressures and volumes, assuming in one case that the temperature of the air before admission to the compressor is zero, in another sixty degrees, and in another one hundred degrees.

Beginning with the adiabatic curve, we find that for one volume of air, when compressed without cooling, the curve intersects the first vertical line at a point between 0.6 and 0.7 volume, the gauge pressure being 14.7 pounds. If we assume that this air was admitted to the compressor at a temperature of zero, it will reach about 100 degrees when the gauge pressure

is 14.7 pounds. We find this by following down the first line intersected by the adiabatic curve to the point where the zero heat curve intersects this same line, the reading being given in figures to the left immediately opposite. If the air had been admitted to the compressor at 60 degrees, it would register about 176 degrees at 14.7 pounds gauge pressure. If the air were 100 degrees before compression, it would go up to about 230 degrees at this pressure. Following this adiabatic curve until it intersects line No. 5, representing a pressure of five atmospheres above a vacuum (58.8 lb. gauge pressure), we see that the total increase of temperature on the zero heat curve is about 270 degrees; for the 60 degree curve it is about 370 degrees, and for the 100 degree curve it is about 435 degrees. The diagram shows that when a volume of air is compressed adiabatically to 21 atmospheres (294 lb. gauge pressure) it will occupy a volume a little more than one-tenth; the total increase of temperature with an initial temperature of zero is about 650 degrees; with 60 degrees initial temperature it is 800 degrees, and with 100 degrees initial it is 900 degrees. It will be observed that the zero heat curve is flatter than the others, indicating that when free air is admitted to a compressor cold, the relative increase of temperature is less than when the air is hot. This points to the importance of low initial temperature. It is plain that a high initial temperature means a higher temperature throughout the stroke of a compressor. The diagram gives the loss of temperature during compression from initial temperatures of 0 deg., 60 deg., 100 deg. If we compare the compression line from zero with the compression line from 100 deg., we observe that in compressing the air from, say 1 atmosphere to 10 atmospheres, the original difference, which at the start was only 100 deg., has now been about doubled; that is, it has reached 200 deg., and in carrying the compression to 20 atmospheres

the difference now becomes about 250 deg. Each horizontal division represented by the figures at the left is equal to 100 deg., and the space between any two adjacent horizontal lines may be subdivided into 100 equal parts representing 1 deg. each.

Where there is a system of cooling the air during compression, the lines on the indicator cards can be traced between the adiabatic and isothermal curves on the diagram. In practice the best compressors show a line about midway between these two curves. Compressors using a spray of water for cooling show a pressure line a little nearer the isothermal, but for reasons which will be referred to later on, spray compressors are now but little used.

For all practical purposes in using this diagram it is best to follow the adiabatic curve in all determinations, except where the exact pressure line is known. This diagram will be found convenient to those who are called upon to figure the pressure at different points in the stroke of an air compressor, and it points out the common error of neglecting to take into consideration in one's figures the fact that, at the beginning of the stroke, one atmosphere in volume already exists. Beginning at the upper left hand corner, the adiabatic pressure curve intersects the first vertical line at that point in the stroke when the pressure on the gauge will register 14.7 pounds.

The next vertical line shows where the gauge reaches 29.4 pounds, and it is evident here that the piston of an air compressor travels much farther in reaching 14.7 pounds than in doubling that pressure or in reaching 29.4 pounds; thus an air compressor is an engine of unevenly distributed resistance. During the early stages of the stroke it has a slowly accumulating load to carry, while later on this load is multiplied very rapidly. This is one of the reasons for heavy fly wheels in air compressors.

W. L. SAUNDERS.

## COMMUNICATIONS.

Editor COMPRESSED AIR:

I was much pleased to receive a copy of the first issue of your paper, which is to be "devoted to the useful application of compressed air," and feel sure that, with such an extensive subject, it will grow—with careful nursing at first—from the small new-born babe which it now is, to be a veritable giant.

It is now over twenty years since the subject of the application of compressed air to street car propulsion was in a manner forced upon me.

I was at the time, and had been for about six years previously, a draftsman in the employ of the Fairfield Engineering and Shipbuilding Co., on the Clyde, when the Scott-Moncrieff compressed air street motor was brought into the works to be tested on the yard tracks. The application of compressed air for any purpose was entirely new to us, and we turned out of the office to witness it.

The general feeling among us, in which I largely shared, was one of sympathy for the poor, deluded, crazy, crank of an "inventor" who would waste time and money on what we at first supposed was such an uncertain and expensive means of storing and transmitting power. We imagined that the losses—first of compressing the air, and then in using it as a motive power—would be enormous, to say nothing of the losses by leakage. We also pictured to ourselves and discussed the chances of getting stalled in the middle of a trip by the storage supply giving out, especially if some unexpected leaks should occur. In fact, we were all agreed that the odds were against it, and that it must prove a failure. It did prove a failure, but not for reasons mechanical as we expected. The reasons were financial.

It is astonishing how much professional prejudice exists, and how much our feelings then are still shared by mechanical

engineers of to-day, even to the extent that many consider time spent investigating or discussing the subject as wasted, and therefore decline either to investigate or discuss. There are some who, never having studied the subject, and having no experience with it, think it a very simple matter to compress air and use it for power purposes. I would advise such to study the intricacies of the Westinghouse air brake. They will find that a good deal of intelligent study has been given to this one subject alone, and a remarkable amount of ingenuity displayed, though at first sight it may seem a very simple proposition.

There are others who, having no mechanical skill or experience, nevertheless regard themselves as born geniuses, and who, posing as "inventors," patent some of the most absurd contrivances. An examination of some of their patent specifications is amusing if not instructive. As Prof. Rankine put it, "they are misled by their own ingenuity." These men, as a general rule, have a "gift of the gab," and they are more often successful in enlisting capital to exploit their "inventions" than those in which there is real merit. Compressed air is a favorite subject with these "cranks," and the result is that discredit is to a great extent thrown on compressed air by the failure of their unmechanical and chimerical schemes. My reason for referring to them is that I am told so many times, "Oh, compressed air has often been tried and proved a failure." The above is one of the causes, and another the lack of proper financial backing.

I have said that the subject of compressed air was practically forced upon me, and will now state how I became a convert.

A few months after witnessing the first performance of the Scott-Moncrieff motor, and having formed my opinions of it—opinions based on prejudice, of course, for I had not given the matter proper and careful study—Scott Moncrieff, who was not a practical mechanic, wanted an "all-

around" practical mechanic and draftsman to "assist" him. I was recommended for the position, having then had ten years' shop and six years' drawing room experience, and so it was offered to me.

Having adversely criticized the "invention," and formed opinions that it did not possess the elements of success, I hesitated; but as the salary offered was greater than I then received, was tempted to accept. Very soon after entering on my new duties, it began to dawn upon me that my criticisms had been unjust, or at least not wholly justified, and as we made improvements I became enthusiastic as to future possibilities. Some of my friends have since regarded me in the same light that I originally regarded Scott Moncrieff; but here let me say that just as in my case, and without exception, all those who have thoroughly investigated the subject have become convinced, and one gentleman recently made the witty remark, referring to those who came to witness the latest development in compressed air motors: "Even those who come to scoff, remain to pray."

ROBERT HARDIE.

ROME, N. Y., April 4, '96.

### Compressed Air in Underground Work.

So much has been said regarding the use of compressed air in mining, that very little is left to be said. But I find that with all the information scattered from one end of the continent to another, there are a number of mining superintendents and foremen, in the Western mining country particularly, who are ready at all times to argue against its use. Their arguments are sometimes reasonable; for instance, when the question of expensive fuel comes up. But most of their arguments are unreasonable, and to prove this we will commence with rock drills, and where they can be used economically; sinking shafts and winzes, driving drifts and upraising, and in a large majority of cases for stoping.

In sinking by hand, a good day's work for three men would be the drilling and blasting in medium hard rock of four holes three feet deep each. These four holes would just about make the sump two feet deep; the other two shift's work, if working eight hours each, would hoist the debris and drill the holes to square the shaft, making in depth two feet in 24 hours. Had a compressed air rock drill been used for this work, all the holes necessary for blasting the bottom of a shaft 8 or 9 feet long by 5 feet wide, could be drilled in one shift of 8 hours; and instead of taking out a sump to square two feet, as done by hand, the machine in the time stated would drill the holes deep enough to take out a sump to square four feet—doubling the work at an extra cost of an engineer and the fuel; or, in other words, instead of sinking 45 to 50 feet per month by hand, 90 to 100 feet would be sunk with machine drills, and I think shows conclusively the economy of their use.

But with facts of this kind presented, we are told they are not economical, and the reasons given are that sinking by machine drills break out too much of the sides or walls of the shaft, requiring a great deal of filling and wedging behind the timber, and in blasting the debris was thrown so high up the shaft that it cut out the dividing timber, and the time lost in the filling and repairing the shaft would more than offset any time gained by using machine drills.

To disprove these statements we would ask, why should the holes drilled by a machine have a greater burden to remove than a hole drilled by hand? and with the same judgment used in planning or marking out the position of the hole to be drilled, the same results should be obtained and all the holes necessary to make the sump and stope holes to square the bottom would be done in one-third the time; showing a saving of not less than one-half the cost of

drilling compared with hand labor. But experience shows that the holes should be drilled by a machine with a greater burden, for the reason that the diameter of the hole is much larger than a hole drilled by hand; and (as an illustration) where a hole is drilled by hand, say 4 feet deep and 1 inch diameter, and in the opinion of the miner charging the hole he should insert powder enough to fill it up one foot to remove the burden and prevent the breaking out of the sides and cutting out the dividing timber. Now, if a machine hole be drilled with double the burden the same depth and about 1 3/8 inch diameter at the bottom, one foot of powder would be about double the quantity there would be in the hand-drilled hole; and if the resistance is double in the machine-drilled hole, why or by what cause, providing the hole was practically pointed, should this hole break further into the walls of the shaft, or throw the debris up the shaft to cut down the timber? The only answer that suggests itself is: If any difference in results was shown, it was not because the hole was drilled by a machine, but for this reason: the hole or holes were improperly pointed, or the charge of powder was too great to remove the burden in a safe and economical manner.

If this is correct, is it not economical to use machines? Aside from this, you have the benefit of ventilation. The work done in one-half less time, the benefits derived from this in most cases is worth to the mining company one-half the actual cost of sinking the shaft.

No one questions the economy of the rock drill in drifting and raising and in stoping.

East of the Missouri River, in Africa and Great Britain shaft sinking is done successfully by machine drills operated by compressed air, and there is no reason why every shaft in the United States that requires drilling should not adopt the rock drill and use of compressed air.

Many advantages are also gained by compressed air for pumping; no condensation of steam, no change necessary in the pump for its application. Mine timbers are kept dry and preserved. It prevents arches and pillars in the mine from slackening and crumbling; can be applied to small hoists for hoisting the debris out of winzes, raising timber, etc.

Many mines have soft or what is termed running ground, very difficult to timber. If in drifting the breast has to be close timbered in sections, the advancement is very slow. A great deal of time can be saved by putting in an air lock and using 30 to 40 pounds pressure of air. This will in most cases allow the miners to advance very rapidly and far enough for a set of timber, and the set of timber put in in the ordinary way. The cost of a lock in a small tunnel would be no more than the extra cost required for timbering such ground as above described for the advancement of 6 feet of three sets of timber in the ordinary way.

WM. M. TREGLOWN.

SENATOR MCMILLAN, U. S. Senate, has reported favorably on a new bill to extend the routes of the Eckington & Soldiers' Home and the Belt Line Railway companies of Washington, D. C. The bill provides that within three months from the passage of the act those portions of the two lines within the city boundaries shall be equipped with compressed air motors. If, after a trial of three months, the Commissioners find the compressed air motors satisfactory, then they will issue permits to both companies authorizing the use of compressed air motors on their lines within the city, and within six months from the passage of the act both companies are required to abandon the use of horse power on all their lines.

### Compressed Air as Used for Power Purposes.

DELIVERED BEFORE THE ENGINEERING SOCIETY OF COLUMBIA COLLEGE, ON  
APRIL 22D, 1896, BY FREDERICK  
C. WEBER, M. E.

*Professor Hutton and members of the Engineering Society:* The subject outlined for the lecture to-day is "Compressed Air for Power Purposes."

The use of compressed air as a motive power presents many an interesting problem to the engineer, and especially at the present time when almost daily some new use is discovered for compressed air, so that the list of uses to which it is successfully applied is getting so large that it is difficult to keep track of them all.

A slight acquaintance with this power soon convinces one that it is now rapidly asserting its claim to being the *one power* that can be *most generally* applied. Only a few years ago it was restricted to the mine, the tunnel, and for work in confined spaces, and since it was the *only* power that met the essential requirements of these places, the question of economical production and use did not enter very largely into consideration, so that the early compressors were machines of very low efficiency compared with the best compressors of to-day.

As soon as uses were found for compressed air that made economical production an important factor, the compressor began to improve; the improvement has been slow, however, and this subject still offers a big field for investigation. The indicator, which has done so much for the development of the steam engine, seems to have been applied very little at the air compressor, and it is only recently that manufacturers began to take cards from their own compressors.

To understand this subject of air compression in all of its details, some acquaintance with the science of Thermodynamics is necessary, and it seems that an air compressor would not be out of place in a laboratory of an Engineering College, where the heating and cooling effects of the air can be studied; also the question of the jacket and intercooler. The exact size of the latter has not been determined as yet; also the transfer of heat units from air to water through different media. Intelligent investigation would still reveal much to the manufacturer that is unknown to him, and would help to bring the air compressor and air motor upon the same high plane of the steam engine. This has reference especially to compound compressors, the economy of which over the simple compressor is not doubted and about which much remains that is unknown.

#### LITERATURE.

Literature upon this subject is not very extensive; it involves the science of Thermodynamics, and is also intensely practical, so that in order to advance in it a knowledge of the practical and theoretical is necessary.

Professors Wood and Peabody, in their works on Thermodynamics, give considerable space to air compression, the air compressor, and air motor. A. von Ihering, in "Die Gebläse," published in Berlin by Julius Springer, 1893, treats the subject very exhaustively, and his work is really the highest authority to-day on air compression.

Quite a number of articles on compressed air and air machinery in general have appeared from time to time in the various technical journals, chief among them the *American Machinist* and *Scientific American*. Within the past month a paper called "COMPRESSED AIR" has made its appearance; it is devoted principally to the subject of air compression, and contains both theoretical and practical considerations on this subject.

## PRINCIPAL USES.

Chief among the uses to which compressed air is applied may be mentioned:

- Driving rock drills.
- Operating air hoists.
  - moulding machines.
  - sand blast.
  - chipping castings.
  - air brakes.
- For cleaning car seats.
- switch and signal service.
- the Pohle air lift pump.
- sinking caissons.
- caulking.
- Operating motors.
  - street cars.

A complete list of uses up to date will be found in a work on compressed air by Frank Richards, published by John Wiley & Sons, 1895.

Its use in the mine and tunnel is probably as yet the most general, owing to the peculiarity and confined nature of this work, and other considerations, both mechanical and economical, which exclude steam, water and electricity.

Soon, however, some of the many other uses to which it is applied will equal in importance its use in the mine.

## RAILWAY.

The railway companies all over the country recognize its importance in the safe handling of trains under very high speeds, and its position in the railroad shop and foundry will be hard to replace with any other power.

## POHLE PUMP.

The Pohle pump is a valveless pump; the air under pressure is liberated at the bottom of a well, and by virtue of its expansive force it raises a column of water from a depth at which the ordinary piston pump fails.

Sometimes a piston pump is placed so far from the steam-boiler that condensation losses in the pipes and heat generated when the pump is working in a confined

space, give compressed air the advantage in operating this style of pump.

## TRAMWAY.

Another important use is its use on the tramway, or in operating street car motors. I propose to deal somewhat at length upon this particular use; and since its application here involves high pressures, the compound compressor will receive a greater share of attention at the end of this article, and I will restrict myself to the use of high pressures as applied in the Hardie motor, having with others made an exhaustive test on this motor in May, 1895.

## PRODUCTION.

*Physical Properties of Air:*

Air is considered a perfect gas, and is therefore subject to the natural laws affecting perfect gases.

## WEIGHT.

The weight of one cubic foot of dry air at temperature of melting ice and at barometric pressure of sea level (29.92 inches mercury), is .080728 lbs. (M. Regnault.)

## VOLUME.

The volume varies inversely as the density; or,

$$V = \frac{1}{W} = 12.387 \text{ cubic feet per lb. (at sea level and at temp. of melting ice).}$$

## PRESSURE AND TEMPERATURE.

Under constant pressure its volume varies directly as the absolute temperature.

For constant volume the pressure is proportional directly to an increase in temperature, when expressed algebraically—

$$\left( \frac{V_A}{P_A} \right)_P \propto T \quad \left( \frac{P_A}{V_A} \right)_V \propto T \quad \text{----- I}$$

or by combining Boyle's law with that of Gay Lussac—

$$\frac{P_0 V_0}{T_0} = \frac{P_1 V_1}{T_1} = C \quad \text{----- II.}$$

$P_0$  = Atmospheric pressure at sea level.

$T_0$  = Temperature (absolute) of melting ice.

$V_o$  = Volume of one pound at that temperature ( $T_o$ ) and pressure ( $P_o$ ), and is a function of the density.

$P_i, V_i, T_i$  are specific values

$C = 53.21$  for air.

#### SPECIFIC HEAT.

Air has two specific heats, one at constant pressure - - - - .2375  
the other at constant volume - - .1689

The ratio of  $\frac{C_p}{C_v} = n = \frac{.2375}{.1689} = 1.4061$

#### GENERAL PRINCIPLES OF COMPRESSING.

##### Work of Compression :

(Simple compressor.)

$W = P_1 V_1 \log_e \frac{P_2}{P_1}$  foot pounds (isothermal).....III.

$W_i = P_1 V_1 \frac{n}{n-1} \left[ \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$  foot pounds (adiabatic).....IV.

when  $V_i$  = volume of one pound of air at the pressure  $P_i$  and compressed from  $P_i$  to  $P_2$ .

#### COMPOUND COMPRESSORS.

$W_2 = P_1 V_1 \frac{n}{n-1} \left[ \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} + \left( \frac{P_3}{P_2} \right)^{\frac{n-1}{n}} - 2 \right]$ .....V.

when compression is done in two stages and cooled to atmospheric temperature between stages.

$P_2$  = Intermediate pressure, and work done is a minimum when

$$P_2 = \sqrt{P_1 P_3}.$$

#### COMPRESSION.

The first law of Thermodynamics tells us that heat and mechanical energy are mutually convertible ; therefore, when the piston of the compressor is made to do work, heat is produced in exact proportion to the amount of work done (in the ratio of one B. T. U.) for every 778 ft. pounds expended.

Since, however, the usual conditions under which compressed air is employed place the motor at some distance from the compressor, this heat of compression is soon dissipated to the surrounding media, and this loss of heat then represents lost

work, so that it is very desirable to be able to compress the air with as little increase in temperature as possible.

If the temperature could be kept constant throughout the compression, this process would be called an isothermal or equal temperature process, and if no heat passed to or from the air during compression it would be termed an adiabatic process.

The loss due to the heat of compression is the greatest loss in the production of compressed air, and to prevent this loss a cooling medium is supplied that will abstract the heat during compression. Water is usually employed, and it has been used in various ways, calling into existence two distinct classes of compressors—

1) Wet compressors.

2) Dry compressors.

In the first class water is introduced directly into the cylinder during the compression process, and in the second class *no* water is admitted to the air during compression.

Wet compressors are subdivided into two classes—

a) Compressors in which water is sprayed into the cylinder during compression, and

b) Those which use a water piston for compressing.

The first class of wet compressors has shown the highest degree of efficiency for one stage (or simple) compressors, because the water is thoroughly mixed with the heated air and takes up the heat readily (due to the difference in the specific heats of water and air). The injected water must not be excessive, or damage will result to the compressor. An increased capacity also results from using water in the cylinder to fill the clearance spaces.

Although the spray injection compressor will show a higher thermo-dynamic efficiency than the dry or jacketed compressor, its commercial efficiency is not so high, for water in the cylinder prevents proper lubrication; impurities in the water

also attack the walls of the cylinder, and the moisture in the air causes freezing of the delivery pipe in cold weather, also choking of exhaust in motor due to freezing, resulting from low temperatures of expansion.

The hydraulic piston or plunger compressor has a very low efficiency, and is now obsolete.

In the Dry Compressor the external walls of the cylinder are flooded with water, the cooling effect is not as great as in the spray injection compressor but it overcomes all of the disadvantages of the Wet Compressor

intake valve, about  $\frac{1}{4}$ " is allowed between valve and seat, this is sufficient to admit a free inflow of air; there is no loss in vacuum due to late opening. On the compression side the pressure line begins to rise very close to the beginning of the stroke and increases until slightly in excess of the receiver pressure when the discharge valve (H) opens and the air is now forced into the receiver until the end of the stroke. The crank is now passing the center and for an instant the piston comes to a stop before it goes on its return stroke, during this operation the spring in the discharge valve

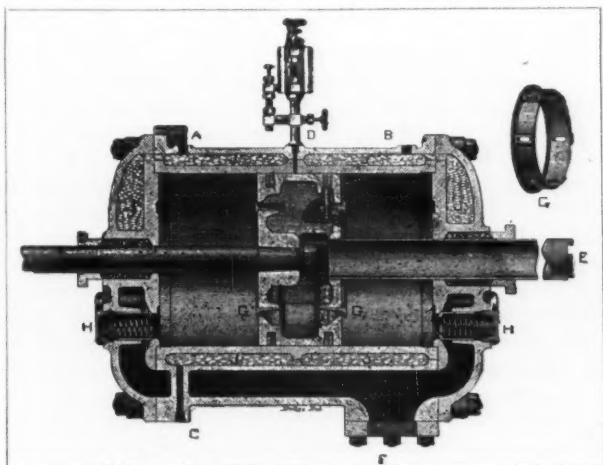


FIG. 1.

—it is very popular in this country while the spray injection compressor seems to be the popular compressor abroad.

Fig. 1 shows the jacket (J) applied both on head and sides of a cylinder of the Ingersoll-Sergeant Compressor.

The air enters the cylinder through the hollow tail-rod (E) the inlet valves (G) being placed inside the piston. At the beginning of the stroke both inlet valves remain stationery, due to their own inertia and the piston moves towards the valve on the compressing side and away from the

combined with its weight forces the valve to its seat, cutting off all communication between receiver and cylinder—the air that remains in the clearance spaces expands back to atmospheric pressure and then admission for the return stroke begins and the same cycle is completed as described above.

#### SOURCE OF LOSS.

The Efficiency of an Air Compressor is often stated in terms of the mechanical efficiency and the efficiency of compression, this is the truth but not the whole truth,

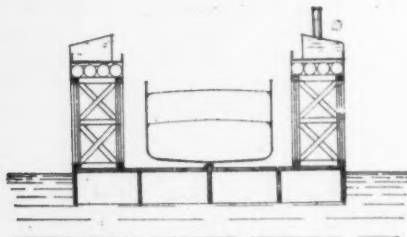
for in every Compressor there are two losses which effect the capacity or the amount of air delivered—the *first* of these losses is that due to the heat of the inlet valves by the friction of the air in passing into the cylinder—the ingoing air coming in contact with these hot valves expands and consequently a less weight of air is admitted per stroke.

[TO BE CONTINUED]

### Compressed Air Dry Dock.

We illustrate herewith a dry dock, the invention of August Geiger, engineer, of Portland, Oregon, operated by compressed air. The dry dock is of the floating type, but unlike ordinary floating dry docks, it *has no bottom*, so that the water can flow in and out with perfect freedom. This dry dock has no pumping machinery; in its place an air compressor is used. The compressor is located upon an elevated platform, running parallel with the long sides of the dock, and is connected by pipes to the different water-tight compartments into which the dry dock is divided.

In order to lower the dock, valves near the compressor are opened, air rushes out, and water flows in from underneath, causing the dock to sink. When the dock is to be raised, the compressor is started up, air is forced into the compartments, the water is driven out and the dock rises to the surface.



Suppose a vessel of 25 ft. draught (about the greatest draught steamers have) was to

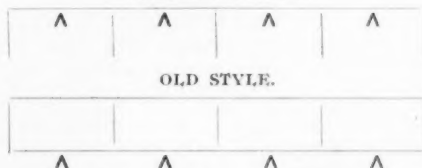
be docked. It would be necessary to sink the dock about 28 ft., and in order to raise it air pressure of about 14 pounds to the square inch would be required. The higher the dock is raised, the less pressure is needed.

Assuming a dock of 300 ft. length, 80 ft. width and 7 ft. depth, we have a large box of  $300 \times 80 \times 7$  ft., = 168,000 c. ft. This amount of compressed air is necessary when the dock is out of the water, but as the water displaced has only 7 ft. depth, = 84 in., the pressure required is only  $84 \text{ in.} \div 28 = 3$  lbs. per square inch. As the lifting capacity of a dock is equal to the weight of displaced water, it would be in this case, if in a river,  $168,000 \text{ c. ft.} \times 62 \text{ lbs.} = 10,416,000 \text{ lbs.} = 5,208 \text{ tons}$ , less the weight of the dock itself.

One great advantage of such a dock would be the bottomless construction, which in a dry dock of  $300 \times 80$  ft. means a saving of 24,000 sq. ft. of water-tight flooring and caulking, which is quite an item; and with this system a cheaper dock can be built than with the old-style pumping machinery.

Another point in favor of this style of dry dock is, that the lifting power acts under the upper side of the big box, which makes it steadier and less liable to topple over than with the ordinary dry dock, where the lifting power acts under the under side of the big box.

PNEUMATIC DOCK.



Mr. Geiger thinks that compressed air could be more quickly furnished to raise the docks than it would be possible to pump water out by the old system. The pipe connection would be smaller, and in general less machinery would be required.

## NEW CANAL LOCKS.

A pneumatic canal lock, designed for use in the Erie Canal at Lockport, N. Y., is attracting attention of canal builders and engineers. By its introduction the greatest simplicity will be obtained and many of the difficulties experienced in operating locks will be obviated. It is estimated that one pneumatic lock will take the place of the sixteen locks now used at Cohoes.

The principle upon which the Dutton Lock works is described in the *New York Sun* in this way:

"If you were to take two tumblers and fasten them together, bottom to bottom, you would have the equivalent of one section of the new lock. Partly fill the upper tumbler with water and put them both in a tank of water, with the open mouth of the lower tumbler downward. With a straw blow the air into the lower tumbler until it rises almost clear of the water. Now take another pair of tumblers and arrange them in the same way beside the others. Put a U-shaped tube under the two tumblers, connecting the air spaces of each. Balanced upon the compressed air, both sets of tumblers would rise or fall in unison. If you depress one, the other will rise."

The inventor, Mr. Dutton, has developed a wide range of ingenuity in the devices used in the construction of the new lock. When it was first proposed to use air to operate the lock, the size of the pipes and the valves which would be required were looked upon as a settling argument against the method. Nobody thought of making a valve to fit a ten-foot pipe. Mr. Dutton got around the trouble by using for a water seal a U-shaped pipe such as is used for cutting off sewer gas in house plumbing. A 4-inch water cock controls this, and enables a 10-foot pipe to be opened or closed to the air almost as quickly as if a big metal valve were used.

## Fire Alarm Whistle.

A compressed air fire alarm whistle has been invented by F. E. Whitney, of Boston, Mass., and is said to be a most satisfactory one. Towns that have no available steam for steam alarm whistles will get good results by taking water for pumping the air direct from the street mains. It is now in use at Arlington, N. J., and is being investigated by a large number of fire chiefs who look upon it as a simple and economical method of alarm, in connection with Gamewell or other systems.

E. J. ETZLER, of Tyrone, Pa., is the inventor of a boat whose mode of operation is compressed air. It is simple in construction, and the model will float along by air power. The inventor claims that by his boat more speed can be obtained and a reduction of cost in operation. Thus far Mr. Etzler has not been able to place the boat on the market.

On one occasion Robert Hardie, engineer of the New York Air Power Co., tried the following experiment to explain which has puzzled the experimenter and all others who have heard of it:

An air receiver was filled with compressed air, measures being taken showing the exact volume of air put into the receiver in order to reach a certain pressure on the gauge. The receiver was then partially filled with charcoal, and it was found that more air was required to reach the gauge pressure, indicating that a receiver filled with charcoal would hold more compressed air than it would without the charcoal.

The compressed air machine is no longer an experiment: it is a great commercial fact, a force that must be reckoned with in all the vast uses of modern mechanics. It has come out of its period of infancy into full citizenship in the realm of latter-day industry.

## WHAT IS SAID OF "COMPRESSED AIR."

DENVER, March 30, 1896.

"COMPRESSED AIR" contains within a small space a good deal of power, and will undoubtedly appeal to all users of compressed air as a medium for the distribution of much-needed literature upon this subject.

I am using air not only for drilling, but for hoisting, pumping and ventilation in the Pelican Mine, and, like the "ads" for "Sozodont," will "use none other."

Yours truly,

BENJAMIN B. LAWRENCE.

Dives-Pelican Mine,

810 Boston Bldg, Denver, Colo.

PARIS, April 4, 1896.

I received, some days ago, your lines and the first number of "COMPRESSED AIR," which I read with great interest, and for which I am very much obliged to you.

I think that the publication of a newspaper containing only compressed air matters was a necessity for the American public, who has certainly a great interest for this object without knowing much about it.

I hope you will succeed to educate the Americans to the conviction that compressed air is really the power of the future.

Please to find enclosed check for subscription to "COMPRESSED AIR" for one year.

Very truly yours,

VICTOR POPP.

Societe Generale d'Eclairage et de Force Motrice,

80 Rue Taitbout, Paris, France.

Aside from a few books and occasional articles in the technical press, it can hardly be said that compressed air has a literature. With the widening field for the application of this power a publication devoted to its technical consideration should find a useful field.—*Engineering Record*, April 4th, 1896.

Many interests far less important than this of compressed air have now their representative journals. W. L. Saunders, C. E., the editor and proprietor of the present publication, is exceptionally favored for the collection of the latest developments and data upon this important topic, and the first number contains an attractive array of matter. The illustration of the most popular belt compressor in the world, and another cut showing a strikingly novel and original application of compressed air, cannot fail to make a hit.—*American Machinist*, April 9th, 1896.

This little magazine, the first of its class in the field, is to be devoted to the spread of information relating to the application of compressed air in all its lines. Its editor and his associates are expert in this important branch of science, and judging from the contents and typographical neatness of the first issue "Compressed Air" has a field of its own to fill and proposes to fill it well.—*Engineering News*, April 9th, 1896.

A monthly publication devoted to the useful application of compressed air, has made its appearance in New York. It is attractive in appearance and bids fair to be a worthy representative of a growing industry.—*Western Electrician*, March 28th, 1896.

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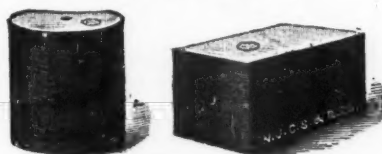
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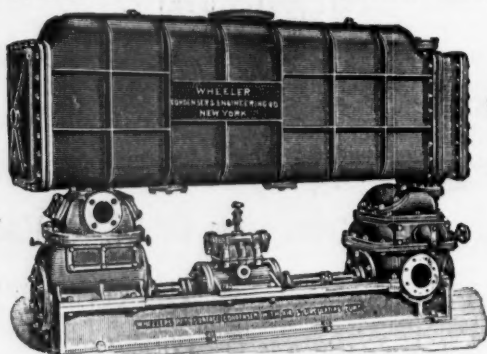
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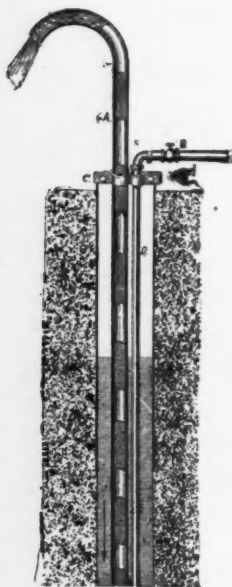


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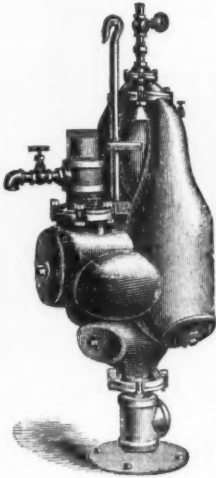
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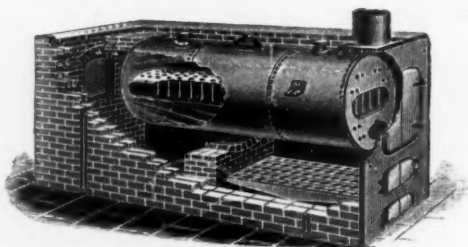
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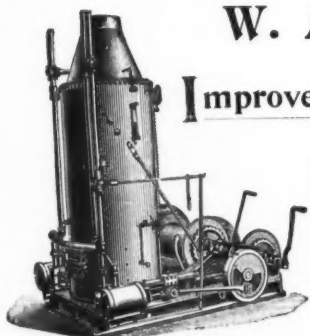


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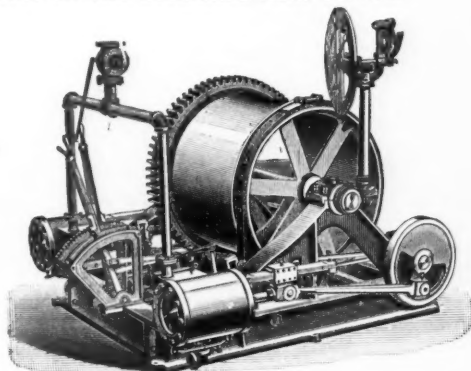
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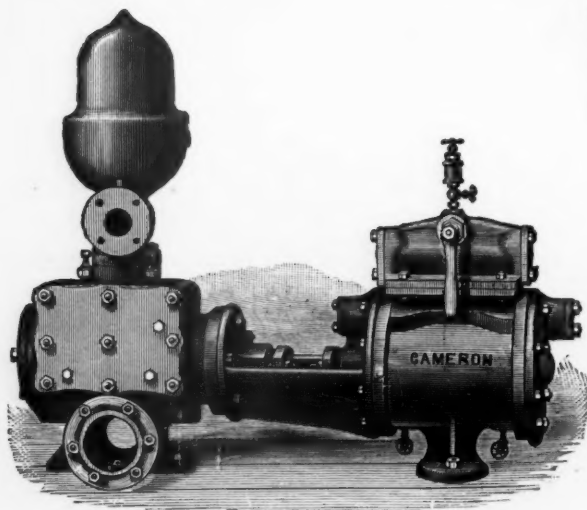
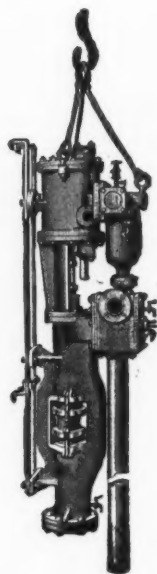
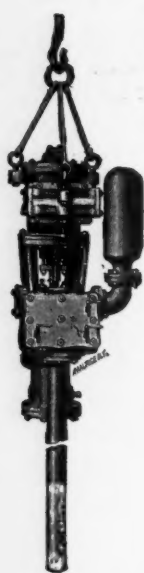
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